AD-A223 036

Diode Laser Pumped

Single Mode 1.3μ Nd: YALO Microlaser

Fairvas?

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The objective of this program was to investigate the implementation of a tunable single frequency Nd: YALO laser on the 1.34μ transition capable of producing several milliwatts of output power. This laser is to be used as a seed source to injection lock a larger Nd: YALO laser. The output from the latter is in turn to be frequency tripled and Raman shifted to match the passband of the Cs atomic vapor filter. Such a system may be suitable for use in submarine laser communication applications.

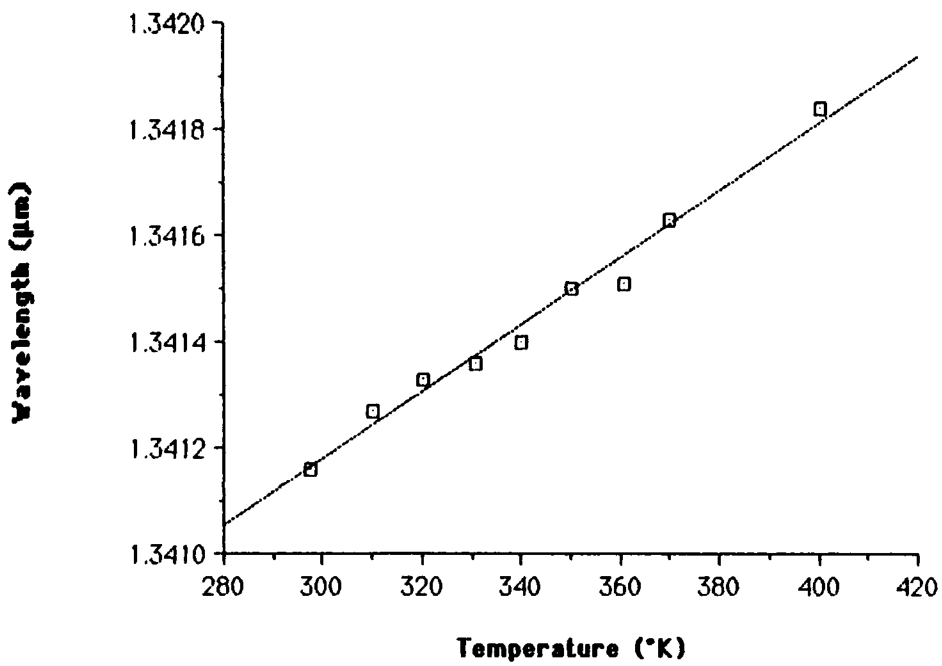
It is desirable to use for the seed source a diode laser pumped microlaser configuration. However, a monolithic microlaser generally is not capable of producing the required amount of single frequency power. Furthermore, the peak of the 1.34μ Nd:YALO transition at room temperature does not correspond exactly to the required wavelength. Therefore, our tasks were to study the temperature shift of the 1.34μ transition and to investigate means of generating adequate amounts of single frequency output - specifically, to examine the output vs. tuning behavior of a two component microlaser incorporating a metal-film mode selector as the output coupling mirror.

The temperature dependence of the transition wavelength was determined by measuring the laser output wavelength of a monolithic Nd:YALO microlaser operated near threshold over a range of temperatures. Under this kind of condition the laser runs on a single TEM_{00} mode, and the oscillation frequency can be no more than half a longitudinal mode spacing away from the peak frequency of the transition. The latter therefore represents the maximum error on each measurement. The rod used for these measurements was oriented along the a axis and had a length of 3mm, giving a longitudinal mode spacing of 26 GHz. At the laser wavelength this translates into a maximum error on

each measurement of $\pm$ 8×10^{-5} μm. The measured laser output wavelength as a function of temperature in the range 300°K to 400°K is shown in Fig. 1. A good straight line fit is obtained, giving a slope of 6.4×10^{-6} $\mu m/°K$.

To increase the single frequency output and promote continuous tunability, we constructed a composite microlaser in which a metal film mode selector served as the output coupler. The details on the fabrication and operation of this device are given in the Appendix. The main results are that with PZT scanning of the gap between the laser rod and the mode selector alone a tuning range (at half power points) of 7 GHz can be obtained, and when it is coupled with the heating of the mode selector a constant power tuning range of 15 GHz is possible. Single frequency output as high as 39 mW was measured.

One possible extension of our work will be a composite microlaser with independent temperature controls on the mode selector as well as the laser rod itself. Such a device should give continuously tunable single frequency output of tens of milliwatts at least between 1.3411 μm and 1.3418 μm.



1.3420
1.3418
1.3416
1.3414
1.3412
1.3410
Wavelength (µm)
280
300
320
340
360
380
400
420
Temperature (°K)

APPENDIX

Tunable Single Frequency 1.3μ Nd:YALO Microlaser

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ABSTRACT

A single frequency Nd:YALO microlaser at 1.3μ using a metal film mode selector has been demonstrated. The maximum single frequency output obtained was 39 mW. Continuous tuning over a range of 15 GHz was achieved with this device.

The spectroscopic properties of Nd:$YAlO_3$ and its laser performance with flash lamp pumping have been extensively investigated in the past.[1-4] With the advent of efficient diode laser pumped solid state lasers in recent years,[5,6] it is of interest to reexamine this laser material under the new mode of excitation. In particular, the $^4F_{3/2}$-$^4I_{13/2}$ transition at 1.34μ has the potential of being useful in underwater laser communication applications.[7,8] For the latter purpose, the precise matching of the wavelength of the up-converted radiation to the passband of the atomic resonance Cs filter is desired. This can be accomplished by heating the Nd:$YAlO_3$ crystal[9] and implementing a single frequency seed source capable of producing a moderately high power output.

We report here the operation of a tunable single frequency Nd:YALO laser on the 1.34μ transition. The laser consists of two elements, the Nd:YALO rod and an etalon output coupler. The etalon is coated with a nichrome film on the inside surface and a dielectric multi-layer on the outside surface. The etalon serves as a mode selector through the periodic modulation of its reflectivity.[10-12] By translating the etalon with respect to the laser rod, tunable single frequency output with varying power can be obtained over a limited range. By combining the translation with the heating of the etalon, one can obtain constant--power single frequency output over a much larger tuning range. This device has been successfully pumped with the output from a dye laser as well as a diode laser array.

A schematic of the laser device is shown in Fig. 1. The Nd:YALO rod is 3 mm in length and is oriented along the b-axis. One end of the rod is curved with a radius of 30 cm, and is coated for maximum reflectance at 1.3μ and high transmittance at 810 nm. The other end is flat and AR coated at 1.3μ. The etalon is made from fused silica and has a thickness of 1 mm. It has a nichrome film on one side and a dielectric coating on the other.

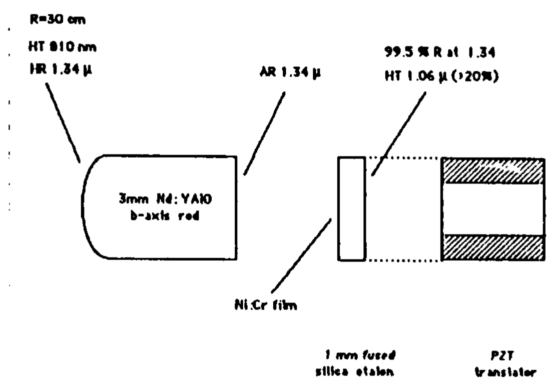

Figure 1. Schematic of Nd:YALO microlaser with metal film etalon output coupler.

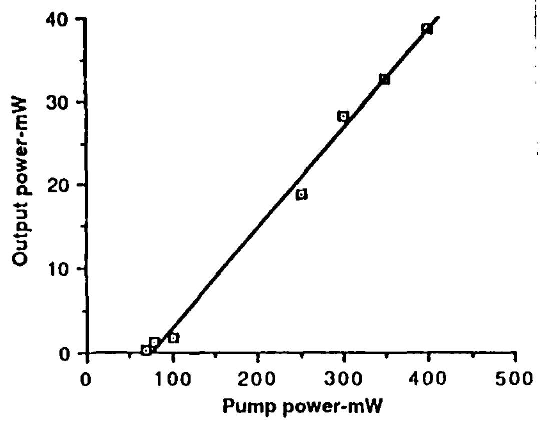

Figure 2. Single frequency output at 1.34μ with 589 nm dye laser pumping.

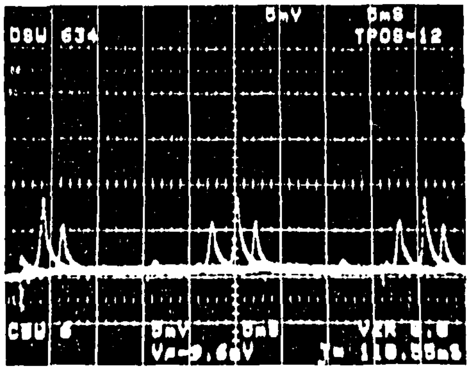

Figure 3. Output of single frequency laser at three different PZT voltage settings as monitored by a 30 GHz spectrum analyzer.

The latter transmits 0.5% at 1.3μ and more than 20% at 1.06μ in order to suppress oscillation at that wavelength. The etalon was mounted on the PZT and was surrounded by a heating element for temperature control. The composite microlaser was built into an aluminum housing which held all the components rigidly in place and insulated the heated components from the surrounding environment. Alignment of the YALO rod to the flat metal film etalon output coupler was accomplished by three fine threaded screws incorporated into the end of the housing in gimbal fashion. In operation, the gap between the laser rod and the etalon was typically on the order of 1 mm. With this arrangement the longitudinal mode spacing for the laser was approximately 20 GHz and the mode spacing for the etalon 100 GHz. These numbers are to be compared with the linewidth of the 1.34μ transition of approximately 500 GHz. The experimental setup used to make the measurements on the single frequency laser included a power meter, a 30 GHz confocal scanning interferometer, and a 1 m monochromator.

When pumped by a CW dye laser at 589 nm with the use of a 10 cm focal length lens, the composite microlaser had a threshold of 70 mW. The output of the laser was linearly polarized with the electric field parallel to that of the pump beam, both along the direction of the c-crystallographic axis. Single frequency output was optimized by fine adjustments of the PZT voltage. The dependence of single frequency 1.34μ laser output on dye laser pump power is shown in Fig. 2. It is seen that a maximum single frequency output of 39 mW was obtained for a pump power of 400 mW, yielding a slope efficiency of 12%. Tuning of the single frequency output resulted directly from sweeping the PZT voltage. Fig. 3 shows superimposed spectral scans of the laser output at three distinct PZT voltage settings as monitored by the spectrum analyzer. We see that the tuning range of the device as given by the half power points was approximately 7 GHz. Changing the PZT voltage beyond the half power points resulted in either mode hopping or multimode operation. The frequency drift of the microlaser was found to be approximately 500 MHz over periods of 1 sec and 1 GHz over periods of 30 minutes. The power stability of the pump laser appeared to be a significant factor in the frequency stability of the microlaser through its heating of the metal film. Depending on the amount of pump power used, the etalon temperature was observed to rise by as much as 5 °C.

By heating the etalon in addition to PZT adjustment, the single frequency tuning range of the device could be significantly increased. Fig. 4 shows typical results of this mode of operation. From the bottom of the figure the traces correspond to the etalon at 25.0, 27.1, 29.5, and 31.3 °C respectively. As the etalon was heated, the PZT voltage was adjusted to continuously keep the output at maximum. We see that over a range of 15 GHz single frequency output at essentially constant power was obtained. Heating beyond the highest temperature caused mode hopping.

The mode-selected YALO laser was also successfully pumped by a diode laser array at 807 nm. This was done

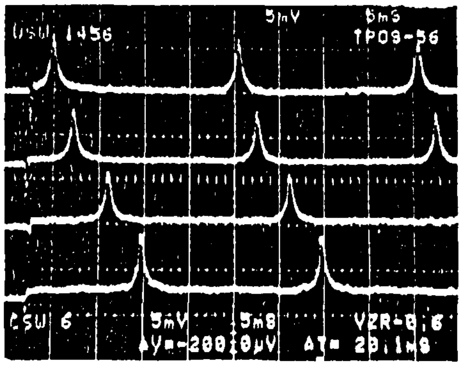

Figure 4. Maximized output of single frequency laser at four different etalon temperatures as monitored by a 30 GHz spectrum analyzer.

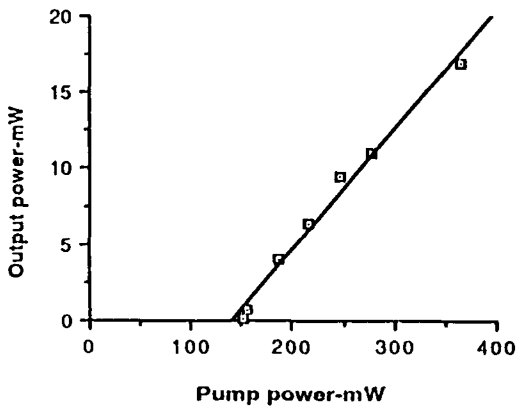

Figure 5. Single frequency output at 1.34μ with 807 nm diode laser array pumping.

by one-to-one imaging of the array output by two AR coated plastic aspheric lenses with a focal length of 4.5 mm. The focusing lens was mounted directly in the sleeve used to hold the Nd:YALO rod, and pump focusing adjustments were made using the collimating lens. Under diode pumping the microlaser had a threshold of 150 mW, and exhibited an output power dependence on pump power shown in Fig. 5. The maximum single frequency output was 16.8 mW for 364 mW of incident pump power, and the slope efficiency was 7.8%. The output of the microlaser with diode array pumping was TEM_{00}, and as before polarized parallel to the pump. We note that the simple focusing elements used did not give optimum mode matching of the pump beam with the 1.34μ laser beam in the YALO rod. As a result, the efficiency for diode array pumping was not as high as that for dye laser pumping, even though the input mirror transmission was greater and photon energy shift smaller for the diode wavelength. A more elaborate focusing system to better match the laser modes should lead to a more efficient diode pumped device.

In conclusion, we have demonstrated a tunable single frequency Nd:YALO microlaser at 1.34μ. Pumping by dye and diode lasers produced conversion efficiencies of 12% and 7.8% respectively. The maximum single frequency output obtained was 39 mW. By combining heating of the metal film etalon output coupler with adjustments in the cavity length, single frequency tuning at constant power was achieved over a range of 15 GHz. The tuning range can probably be extended further with modifications such as the use of an appropriately chosen thinner etalon.

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